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ABSTRACT

Microelectronic technologies have had an impact on the nature of work in industry for both white-collar and blue-collar workers. Evidence from sector- and enterprise-level studies snows changes in skills and job content for blue-collar workers involved with numerically controlled machine tools, robots, and other microelectronics applications. Maintenance jobs have decomposed into two separate functions--electromechanical and electronic maintenance. The introduction of microprocessors into office work has also brought skill changes. Analysis of research challenges the view that loss of production workers' skills is balanced by an upgrading of office workers' skills. In the occupations of designers and drafters, programmers, and clerical workers, a group of semiskilled workers has appeared. Upgrading of some white-collar occupations--specialist engineers, systems analysts, and top managers--has occurred. Industrial training policy implications for developing countries include the need to develop a work force with competence in information technology, to provide practical experience, and to encourage participation of experts from abroad in training. Research into the impact of microelectronics at both the sectoral and enterprise levels and into microelectronics applications and intercountry studies are needed. (An eight-page bibliography is appended.) (YLB)

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Discussion Paper No. 51

MICROELECTRONICS:

THE NATURE OF WORK, SKILLS AND TRAINING

An analysis of case studies from developed and developing countries

by

Liliana Acero

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1. INTRODUCTION

Since the middle of the 1970s, microelectronic technology has spread rapidly to an increasing number of industries and services in the developed world. This has resulted in an important realignment of the processes of production, design, distribution and quality control. As a result considerable changes are occurring in the nature of work, skills and training in a number of occupations.

In the developing world also the diffusion of microelectronics is beginning to make an impact upon the nature of work. This is especially the case for the newly industrialised countries, some of which are now creating their own microelectronic hardware and software. Developing countries generally are beginning to introduce such technology because of the need to compete in an increasingly integrated world economy.

The aim of this paper is to analyse the impact of microelectronic technologies on the nature of work in industry, for white-collar workers as well as for manual workers. The report covers both developed and developing countries and surveys a range of views drawn from published case studies. It will be seen that the literature includes contrasting and contradictory assessments as well as similar or complementary opinions.

The paper is organised as follows: Chapter 2 reviews evidence from sector- and enterprise-level studies on changes in skills and job content for blue-collar workers; Chapter 3 deals with the same issues concerning white-collar workers; Chapter 4 summarises the points arising from the review of published case studies; Chapter 5 considers training and education in developing countries and the policy implications of meeting changing needs; this final chapter also discusses the type of research needed to promote a better understanding of these issues in developing countries.

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I. Microelectronics and blue-collar workers

This chapter explores three levels of skill requirements for production and maintenance workers in industry; the skills of individual workers, those of the different occupational groups in a firm or sector and skills across industrial branches. The analysis focuses on certain new technologies that are widely diffused; attention is paid to the influence of firm size and type of production process on skill requirements and also to national differences in labour use. Labour relations and training policy are also considered wherever information is available. The discussion is based mainly on the findings of case studies carried out in the developed countries; such studies are rare in the developing countries as the diffusion of microelectronic technology is still in its initial phase. Lessons are drawn from the experience of the advanced countries for possible developments in the Third World.

A. Numerically controlled machine tools

The numerically controlled machine tool (NCMT) is the microelectronics-based technology which is most commonly found in industrial production. NCMTs are multi-purpose flexible machines used mainly in batch production for the manufacture of heterogeneous articles. These machine tools are a major innovation compared to previous forms of fixed automation as they are much easier to adapt to different functions and products. With conventional machine tools the worker operated the machine, guiding it to produce parts of a precise size and shape. In the NCMT the information needed to cut or form the parts is programmed and stored in the control unit and a servo mechanism converts the programmed information into the actual manoeuvres performed by the machine. The information is usually coded on a tape which can be filed and recalled when needed.

Analysing the work of a machinist operating an NCMT, Tauile comments: "We might say that the operator's work is deskilled in terms of his manipulative expertise and abilities, and that it is changed and routinised in terms of his mental abilities." (Tauile, 1984a, p. 126.) Some studies indicate that although the skills routinely used by NCMT operators are reduced in scope and complexity compared with those of a conventional machinist, the operator still needs the knowledge and skills to intervene manually when necessary to prevent damage to machines or products (Noble, 1979; Shaiken, 1982; Wilkinson, 1983). Schmitz (1985) has extended this argument and suggests that employers are increasingly concerned with the workers' reliability, as the costs of downtime increase with the degree of automation.

Watanabe shows that practical experience in operating conventional machine tools is the most valuable basis for training in using NCMTs. He shows that experienced workers benefited more from a ten-day course in programming than high-school graduates who lacked practical experience. (Watanabe, 1984.) Sorge et al. (1983) also present evidence that previous experience is more relevant than a higher level of education for an NCMT operator. However, according to Shaiken (1982), a higher turnover of skilled workers occurs among NCMT operators than among conventional machinists in the US. Older, experienced workers suffered from boredom, lack of interest, loss of pride, men-

tal stress, frustration and isolation while working on the new equipment. Younger, inexperienced workers were less intimidated by the new technology and were sometimes enthusiastic about learning to use it.

There is some evidence that recruitment criteria for NCMT operators depends less on skill shortages than on workers' reactions to the new technology (Noble, 1979). Noble describes how labour unions in the US established quotas for the recruitment of skilled workers to use the new technology. In contrast to this, Swords-Isherwood and Senker (1980) show that management resistance to introducing NCMTs was stronger than union resistance in the Federal Republic of Germany and the United Kingdom.

The case studies provide a little information on the effects of NCMTs on workers' skills at other stages of the production process. The new technology performs some of the functions of workers other than machinists, notably those of die-makers. Only 40 per cent of die-construction involves machining, but NCMTs decompose die-casting into simple and complex operations, the simple ones being carried out by the machine. As a consequence, only a small number of highly skilled die-makers maintain their former integral skill. Quality controllers are another group whose functions can be incorporated into the NCMT or performed by its operator, while fitters are made redundant by automatic cutting tool changers. Numerical control thus seems to decompose certain skilled jobs in many branches of engineering and to reduce the number of workers in semi-skilled or unskilled jobs.

With the application of flexible manufacturing systems (FMS), in which NCMTs are linked to robots, human intervention in the machining process is further reduced. For example, when castings are loaded by robots at the beginning of the process and unloaded as products at the end of the fully automated operation, then most workers engaged in materials handling become redundant.

The strategies adopted for recruitment and training of operators for the new equipment in developing countries reflect the industrial organisation characteristic of the Third World. The Brazilian vocational training institution SENAI started giving specialised courses in 1980 in Rio de Janeiro and in 1983 in Sao Paulo, at a time when a considerable number of NCMTs were already in use in Brazil. Tauile (1984a) suggests that, initially, skilled machinists were retrained on the job as NCMT operators, but that more recently firms have started recruiting unskilled workers as operators. In all the firms studied by Tauile, programming was separated from production, so that operators did not need programming skills. Chudnovsky (1985) shows that recruitment strategies in Argentina vary with firm size. The largest firms recruit operators with no previous experience and train them in the firm. Medium and small plants use conventional machinists to work on the new equipment and their training is provided by the machine suppliers. In only one case out of the eight reported by Chudnovsky was programming carried out by the operator. In all other cases programming was done in the office under the supervision of specialised programmers, some of whom had been trained abroad. Jacobsson (1983) notes that there are enough skilled workers, mainly immigrants, in the metal working industry in Argentina for the strategy of retraining conventional machinists to be effective.

The strategies adopted correspond to the characteristics of the markets open to developing countries and to their industrial organisation. Small plant size and small or medium production batches for diversified products, sold in an unstable and differentiated market, have been identified by Katz (1983) as characteristics determining the in-

troduction of NCMTs in Latin America. In these conditions operators need more complex skills to operate NCMTs because they need to respond to new or unexpected problems arising from the changing patterns of production.

In conclusion, it seems that for several reasons the main strategy during the transition period in developing countries will be to adapt and retrain skilled workers. This is because the rate of diffusion of NCMTs is slower in these countries than in the developed countries; because the technology is evolving rapidly and the same plant may be using different generations of equipment, and because of the diversity of products and markets. Large firms, however, generally seem to follow the recruitment and training strategies adopted in the developed countries.

With regard to deskilling, the important point is whether the operator is given responsibility for programming the NCMT on the shop-floor, or whether this is done by a programmer working in an office. Sorge et al. (1981) show that the assignment of programming tasks to operators, setters, foremen or programmers depends on factors relating to the social environment as well as on those relating to the production process and the industry itself. They identified the following elements as points determining the assignment of programming NCMTs: firm and plant size, batch size, the complexity of the components to be produced, the competitive and marketing structures, and national and cultural differences These authors conclude: "The smaller the batch size, the greater the need for frequent conversion of machines with new tools, fixtures and component programmes and the less machine-setting expertise is differentiated from operating. Batch-size economies of scale thus involve a reduction of skills at the operator level." (Sorge et al., 1981, p. 101.)

It can be seen, then, that the conditions in developing countries are less likely to result in a deskilling of the work of the machinist/operator than conditions in developed countries. However, the case studies reviewed do not give a picture of any clear trends emerging with regard to recruitment, retraining or deskilling. In fact, the views expressed by different authors are sometimes contradictory. It is clear that further research is needed before an accurate assessment can be made of the effects of NCMTs, particularly in developing coun-tries.

B. Robots

Numerically controlled machine tools and computerised NCMTs are the most flexible microelectronic-based technologies for batch production, but for mass production robots are the most reliable and versatile technology. Robots can, of course, also be used in conjunction with NCMTs for batch production in flexible manufacturing systems (FMS). In the engineering industries NCMTs change the nature of the work of skilled machinists but robots mainly affect the jobs of unskilled or semi-skilled workers, each robot replacing two or three workers. A robot is a general purpose machine resembling a jointed arm which can move a tool or working part to a location specified by its control. It can either have a "point to point type control", useful in heavy lifting, or a "continuous path type control", ideal for tool manipulation (Brady and Miles, 1982), Some robots can switch to a completely different activity, simply by changing the programme, and change-over times are much shorter than those required in fixed automation systems. However, in Europe robots are mostly used for fixed automation i.e. applied to only one activity, in big firms (ILO, 1985; Jacobsson and Ljung, 1983). The OECD estimated that in 1982 there were 31,000 robots installed in its member countries, with Sweden registering the

highest diffusion rate. However, Japan has been the leading country world-wide in robot utilisation, with an estimated total of 13,000 units (Coriat, 1983, p. 39). The rate of diffusion in developing countries is still low (ILO, 1985, p. 26). There were five robots in Argentina in 1983, installed in multinational car firms (Chudnovsky, 1985) and 20 in Brazil, also in the car industry (Tauile, 1984b). More up-to-date information on their overall numbers is not yet available.

Robot-type manipulators first began to be used in the early 1960s but their real diffusion started when they were equipped with a microelectronic-based control unit (Jacobsson and Ljung, 1983, p. 150). Industrial robots are classified as handling robots, process robots and assembly robots. They are mainly used in the production of cars and of domestic electrical appliances.

At present there are two generations of robotics technology, which have different effects on labour requirements. The first generation of machines cannot respond to the environment as they lack sensory devices and feedback. They can only learn pre-set behaviour and cannot adjust to needs so that they continue working even if something goes wrong during the operation. Their application to assembly work is limited to handling only very regular components.

The second generation of robots is not yet fully developed. Research is still in progress on tactile sensing and vision systems: the sophistication of sensors is central to light assembly work, machine loading and inspection. At present the successful use of robots in production depends on having a sufficiently standardised environment and organisation of work; research in industrial robotics is therefore aimed at developing universal-type robots as well as machines for specific operations. The latest generation of robots will transform assembly-line production which, of course, cuts across many different branches of industry, from the assembly of electronic components in the semi-conductor industry to the manufacture of car bodies.

In the conventional production process, assembly-line work is heavily fragmented and is carried out by unskilled or semi-skilled workers. The monotonous nature of work in the early stages of assembly-line automation resulted in high rates of absenteeism, labour turnover and strikes in the late 1960s. The sequential nature of tasks in fixed automation made the assembly-line vulnerable to many forms of industrial action, including go-slows and work stoppages. Interruptions at one workstation had repercussions all along the line. In the late 1960s enterprises began to make attempts to restructure the organisation of work along the assembly line from fixed, individual workposts to sub-assemblies with team workstations. Partridge (1982, pp. 18-23) shows that at several Italian FIAT plants these innovative forms of work organisation failed to improve efficiency or work discipline. As a consequence robots were introduced in many FIAT plants with the intention of drastically reducing the workforce.

The first robots were introduced in small numbers to perform tasks which were a health or safety risk, and thus met little resistance from workers. The CSE Microelectronics Group (1980, p. 68) says of their introduction in the United Kingdom: "The majority of robots in Britain have been installed because management could not keep workers in particularly dirty jobs for the wages they were willing to pay." In Italy the introduction of robots was actually stimulated by the unions' demands to eliminate tiring and unhealthy working conditions (Silva et al., 1984).

Management and machine suppliers frequently assumed that robots could dispense with human intervention. However, a review of case studies on the employment effects of

robotics casts doubt on this assumption. Shaiken (1982) shows that first generation robots, mainly parts-handling and process robots, could rarely be used without an operator. As the robot was not sensitive to the environment an operator had to lead it across hazardous areas or else check over and perfect the work that the robot had done. The operators' responsibilities extended beyond merely supervising the robot. Second generation robots will facilitate the tasks of their human operators but it is doubtful whether these jobs will be completely eliminated.

Coriat (1983, p. 86) argues that in both assembly-line and continuous-flow production a high level of initiative and quick decision-making is required from operators, who must intervene rapidly if something goes wrong. On the assembly line production levels depend on the workers' rhythm of work, making swift action crucial. Assembly workers do not only supervise robots; a lot of assembly work is still performed manually. It is still highly fragmented and has to be carried out rapidly, especially if compared with continuous process industries.

The introduction of assembly robots in France has been accompanied by two different strategies regarding labour. One is to lay off unskilled workers, while keeping a small number of semi-skilled workers in charge of the line. The other is to create a group of specialised workers trained to diagnose and solve problems in the automated unit. This requires a good understanding of the technology and the capacity to keep the line running smoothly by intervening manually when necessary. Relative freedom of movement is granted to workers along the line, who must be constantly on the alert for breakdowns. There is no evidence in the literature of how many manufacturers in France adopt the strategy of creating a special group of workers responsible for the robots, but it is clear that when this happens some workers do have the possibility of upgrading their skills.

In the US all the major car manufacturers have now been forced by trade union agreements to train their skilled workers in electronics and programming. And in the United Kingdom the Technical and Supervisory Staffs Association (TASS) has made an agreement with management giving them exclusive programming rights for robots (CSE, 1980, p. 69).

The effect of robotics on the skills of production workers depends upon how robots are used in production and which workers are trained to programme them. Most programming for robots is by the analogy method, which semi-skilled workers can be trained to carry out. With this type of programming the robot learns by reproducing the movements made by a worker, e.g. while painting a car. The robot simply repeats the memorised sequence of operations, thus eliminating the need for the time and motion studies which are required for programming NCMTs.

Recent publications question the extent to which the quality of working life has improved as a result of introducing robots. Some workers have certainly experienced a deterioration; their job content consists mostly of feeding materials, the pace of work has intensified, night shifts have been introduced, freedom of movement has been reduced and the need for constant attention is stressful.

It has been predicted that robots would make little impact on industry in developing countries as low wages are the most important advantage of these countries and reducing labour costs is not an important consideration. However, there is some evidence that robots are increasingly being introduced in the Third World. The few case studies available identify the main reason for

using robots as the need to maintain product specifications and quality standards for export. This has to be seen in the context of the multinational corporations' policy of following production standards set by the head office.

Tauile (1984b) discusses how the production of the world car in Brazil has led multinational car assemblers to introduce the most sophisticated microelectronics technology, including robots, in order to reach standard quality levels and model specifications throughout their companies. He quotes a local study which estimated the diffusion of robots in Brazil as reaching about 10,000 by 1990, which could cause the loss of between 20,000 and 80,000 jobs. Tauile argues (p. 15) that the pay-off period for a painting robot is 32 years in Brazil, and that for a spot-welding robot the pay-off period is ten years, given average wages. This shows that reducing labour costs is not an important reason for introducing robots. Tauile is aware, however, that the savings in labour costs may not derive strictly from the direct use of the equipment but rather from gains in the factory's overall productivity.

Tauile identified no skill shortages among production workers. The most common practice adopted by the firms he studied was to train former production workers to programme the robots. In contrast to this, an analysis of the situation in Argentina by Chudnovsky (1985, p. 506) shows that former operators usually only supervise the robots while programming is carried out by specialists trained by the machine suppliers. His conclusions also contrast with those of Tauile in that he found that in Argentina the multinationals did not necessarily introduce robots to produce export goods but simply in order to keep up with innovations made by the parent company.

The case studies reviewed frequently, stress that microelectronic equipment lowers the skill component in production work and reduces human intervention in the process generally. The possibility arises that the labour-intensive assembly industries installed in developing countries might return to the developed countries, thus increasing unemployment in the South. However, there is little evidence that this is taking place.

Experience in some newly industrialised countries shows that the establishment of assembly industries has stimulated the expansion of local capabilities in many areas, including the design of electronic equipment (Clarke and Gable, 1982; Tigre, 1983). Future developments in light assembly robotics may help diffuse this sophisticated technology in developing countries where assembly industries are concentrated, and may improve their competitiveness in regional markets. The increased use of robots would cause some job losses, but their cost is likely to prohibit any quick and massive diffusion in developing countries. Hence, robot-induced unemployment among unskilled and semi-skilled workers does not seem to be a real threat in the near future.

C. Other microelectronics applications

Blue-collar jobs in many industries are affected by the various applications of microelectronic technology. The following sections briefly review changes in the printing trades, the clothing and textiles industries, and the food and drink industries. The experience of the developed countries is presented first and its relevance for the developing countries is discussed in the final section.

1. Printing

Technology-induced changes in the printing trades are well documented for the US and Europe. One example is a study by the European Trade Union Institute, published in 1982. In the Federal Republic of Germany 35,000 jobs were lost in printing between 1972 and 1979, a loss which was attributed by this study to the introduction of microelectronic technologies (ETUI, 1982).

Before automation all workers in the printing industry needed to be highly literate and numerate and to have good aesthetic sense, manual dexterity and physical strength. The most skilled trades, i.e. linotypists and compositors, served four to six years of formal apprenticeship. Automation developed gradually in different printing operations but the real breakthrough came with the introduction of computerised typesetting and cold composition. With an electronic composition system the text is entered directly through a keyboard on to a video-display terminal and the whole labour process becomes an electronic information system. The main skills now required are the ability to handle computer instruction language and to use a keyboard, which can be learned in approximately two months (Rogers and Friedman, 1980). Cockburn (1983) shows how co-ordination between the team of workers has become vital for the smooth flow of information between different jobs. A collective skill is required from the workforce and all workers need an overall knowledge of the production process.

Technological change is a continuous process. For example, new equipment for reproducing photographs and drawings digitally is expected to affect the work of photographers and photo-engravers in the near future.

There is generally a process of deskilling in the printing industry. It has been found that older workers resist retraining for the new types of work, resenting the fact that the content of formerly skilled jobs has been reduced to typing text into a visual display unit.

It should be pointed out that experience in developed countries may not necessarily be repeated in developing countries. The printers' unions in most European countries and the US were strong enough to negotiate lifetime job security for printing workers faced with automation. Firms therefore adopted the strategy of retraining their skilled workers, which slowed down the rate of job losses. However, workers in the South are not protected in the same way as workers in the North, so that the employment effects of microelectronic technologies on printers' jobs in developing countries can be expected to be even greater than in developed countries.

2. Clothing and textiles

The clothing and textiles industries, traditionally labour-intensive and little mechanised, are undergoing a slow but sustained incorporation of microelectronic technology, mainly in the form of production control devices and monitoring systems. Microelectronic technologies were introduced in the late 1970s, especially in the pre-assembly stages of the clothing industry (grading, marking and cutting). Hoffman and Rush (1984) show that the introduction of computer-aided design and computer-aided manufacturing systems (CAD/CAM) in Europe and the US has sometimes permitted the fusion of these three stages.

The labour process in the clothing industry has changed substantially. Rules for grading can be entered into the CAD system's operat-

ing programme and applied to different master patterns. Graded pieces are checked on a graphic display and altered with an electronic light-pen. According to TUCRIC (1980) CAD operators in the United Kingdom can be trained in six weeks. The cutter's formerly highly skilled job has been greatly simplified with the introduction of numerically controlled machines that receive their cutting instructions on computer tape; training time for a cutter is reduced by 90 per cent.

Assembly work has also been affected by microelectronics. This stage accounted for about 80 per cent of labour in the industry, mostly women workers who operated sewing machines. Three types of technology have been introduced in assembly work: single-purpose sewing machines controlled by NC units; conventional sewing machines modified with input devices or packaged software; conventional multi-purpose sewing machines programmed by the operator. These innovations eliminate the need for the operator to guide the material through the sewing machine, which is the most skilled task in garment assembly. The stitcher becomes a machine-loader and fabric-positioner (Lamphere, 1979). In the finishing stage inspection, pressing and packaging now also incorporate microelectronic controls in the most up-to-date enterprises.

However, Hoffman and Rush (1984) point out that the proportion of firms in the United Kingdom and the US using microelectronics equipment is well below 10 per cent, indicating that the diffusion of this technology is slow. Hoffman and Rush attribute this mainly to poor management, the dominance of small firms in the sector and technical obstacles to innovation, such as low expenditure on research and development, and difficulties in further extending automation. It seems likely that because of very low wages and surplus labour in developing countries the diffusion of new technologies in the clothing industry will be even slower than in developed countries.

Studies of the textiles industry (spinning and weaving) argue that microelectronics will intensify trends introduced by open-end spinning and shuttleless weaving (Rothwell, 1977; MacLean and Rush, 1979). The latest technological development will complement those machines, causing further changes in the work of spinners and weavers, and also in some finishing work which was not highly automated in the past. Examples of advanced machines in the textiles industry are multi-phase looms with microelectronic sensors and controls, electronic mill monitoring and ink-jet printing.

3. Food and drink processing

A wide variety of microelectronic technologies are applied in food and drink processing. They are most commonly used in packaging, which was formerly a labour-intensive, semi-skilled operation, but they are also used in weighing and cooking. The growth in processed food and pre-baked snacks in developed countries (Leach and Shutt, 1984) has further accelerated the diffusion of these new technologies. They include programmable controllers for ovens, microcomputer-controlled machines for packaging and computerised weighing machines that control for product variations.

Bessant and Lamming (1983) list the expected impact of microelectronic equipment on skills in the different stages of food and drink processing. Major deskilling is expected in heat processing, milling and blending, packaging and storing. Human intervention is expected to disappear in sorting, grading and final handling. Less deskilling is expected in handling raw materials and cleaning operations. Certain preservation processes, on the other hand, will demand

higher skills from workers. The authors expect the greatest impact of the new technology to be felt by women workers, as they are concentrated in the tasks subject to deskilling and the operations which are eliminated in the new processes.

Integrated systems for monitoring and process control are being introduced in many food and drink industries. Broddy and Buchanan (1981) report on such systems in automated dough-making at a factory in the United Kingdom. They conclude that it is vital that workers co-operate and share a global understanding of the process in order to avoid downtime and waste. However, the practice of the firm they studied had been contrary to these goals; they had replaced skilled workers with younger, inexperienced operators whom they had failed to train appropriately.

D. Microelectronics in developing countries

There are few published case studies on the labour effects of new technologies in developing countries. The literature that exists stresses that the affected workers are not protected by job security agreements or strong trade unions. It is expected, therefore, that new technologies will make a profound impact on workers' skills, employment opportunities and training patterns in developing countries. In the industries discussed above developing countries have a long tradition of artisan-type skills, both in the informal sector and in medium-size or small enterprises, which are usually subcontractors. For example, in Brazil's clothing industry skilled workers are found in small firms that use non-fragmented labour processes requiring integrated skills, while workers in garment assembly in big firms can be trained in one day to perform the simple operation which is their job (Caulliraux, 1983). The same sort of variations according to firm size and labour organisation are found in the Mexican clothing industry (Mercado, 1980). Long-term availability of skilled and semi-skilled workers has never been a problem in these industries, so it is not unreasonable to expect unemployment and deskilling to result from the introduction of new technologies. There are indications in the literature that some microelectronics equipment is already in common use in large-scale enterprises in developing countries. For example, cold composition already represents 59 per cent of composing facilities in the Colombian printing industry, and electronically controlled rotary presses represent 4 per cent of all installed presses (Ayala, 1985).

The new technologies are usually introduced into large national or foreign firms producing mainly for the domestic market (e.g. Brazilian textiles, Mexican clothing and Colombian printing) or into subsidiaries of multinationals located in free trade zones and producing for export. For example, in the 1970s it became the usual practice for multinationals to ship ready-cut cloth for assembly and finishing to their subsidiaries in developing countries, especially in South-East Asia.

The introduction of new technologies is likely to result in the disappearance of the older generation of skilled and semi-skilled workers from these industries in the developing countries. There is some indication that big firms tend to give priority to the training of young, inexperienced workers rather than retraining skilled and experienced employees.

Developments in the Third World may follow a different pattern from experience in advanced countries with regard to training workers to use microelectronics equipment. The case studies on the developed world

show that only short training is necessary for workers to acquire the new skills needed for the operations affected by technical change. But a higher proportion of experienced workers remain in the industries in advanced countries than is likely to be the case in developing countries. If industry in these countries recruits mostly young and inexperienced workers then longer training periods than those documented for developed countries should be expected. This applies in spite of the deskilling reported for most occupations.

E. Microelectronics and maintenance work

The maintenance and repair of microelectronics equipment is crucial for two reasons. First, downtime costs are high and breakdowns can sometimes affect several stages of the production process. Second, management and sometimes even engineers have little familiarity with the technology of microelectronics equipment (Shaiken, 1982). This applies both in developing and in developed countries. In relation to flexible manufacturing systems Shaiken comments: "The goal of eliminating all worker input results in systems of unbelievable complexity that are prone to breakdowns and thus require considerable amounts of human ingenuity to keep running." (Shaiken, 1982, p. 147).

The maintenance of conventional technology is a highly skilled task which requires training in electromechanics in addition to practical experience. Maintenance workers acquire their skills mainly through on-the-job experience gained through successive promotions from operator to foreman to maintenance worker (Acero, 1983).

The maintenance and repair of microelectronics equipment is generally considered to require new skills. Maintenance involves two distinct activities, relating to the electromechanical part and to the electronic component of the equipment. The maintenance of the electromechanical part tends to become more complex when the machine is linked to a microelectronic component, as the mechanical part is very sensitive and has to respond with great precision to its control mechanism.

Some studies have concluded that the maintenance of the new equipment demands workers with a thorough understanding of different types of engineering principles. It is suggested that such workers should be responsible for whole areas of the plant rather than specific items of equipment as previously. In connection with maintenance in different industries in the United Kingdom Braun and Senker report: "Increased numbers of multi-skilled maintenance craftsmen (or technicians) will be needed. More complex production machinery embodying microelectronics is being installed in a wide range of industries. It is likely that maintenance people with diverse skills will be required increasingly. These people will need to combine mechanical skills with electronic, and for some machines, hydraulic or pneumatic skills as well." (Braun and Senker, 1982, p. 62.) In a later report Senker moves away from the view that there is a need to upgrade increasing numbers of maintenance workers. He suggests instead the concentration of diversified skills among highly skilled technicians.

In addition to the direct effects of microelectronically controlled equipment, the jobs of maintenance workers are also affected by new management information systems. The two main tasks in maintenance are simplified by automatic diagnosis and new methods of repairing electronic control units and systems. In automatic diagnosis, maintenance is systematised and assisted by computer programmes which monitor the

machines. This aids maintenance workers to identify faults; they have access to computer print-outs which record the history of previous breakdowns and repair work for each piece of machinery. Most electronic control systems are now standardised and many are provided with a signalling mechanism which indicates the fault. The faulty component can be removed and either replaced immediately from stock or returned to the supplier for repair or replacement. These new developments suggest an overall reduction in the level of skills required of maintenance workers. Some of the new maintenance systems, integrated into management information systems, monitor the performance of the repair worker. They quantify and display all aspects of the repair operation on a visual display unit. The data are stored in the computer's memory and can be compared with the way the worker performs the same task on the next occasion (Shaiken, 1982). These systems increase management control over the maintenance staff; maintenance is one of the last blue-collar occupations to retain a high level of autonomy in job planning, pacing and evaluation.

However, there are limitations in the new developments which may counteract the deskilling of maintenance work. First, standardisation is still uneven in different microelectronics equipment. Second, as Senker points out: "Automatic diagnosis does not work properly; or, if it does, it only covers a small proportion of the things which could go wrong on a complicated machine." (Senker, 1982, p. 142.) Despite this, it is undeniable that new developments reduce the number of maintenance workers needed per item of equipment.

It is important to determine if the same workers are carrying out both electronic maintenance and mechanical maintenance, and to consider the training they need for each type of job. It seems that the trend is to assign the electromechanical and electronic aspects of maintenance to different groups of workers. Former mechanics or operators are usually trained within the enterprise for electromechanical maintenance, while technicians are recruited from outside the firm for electronic maintenance. In a survey of manufacturing in the United Kingdom Rajan concludes: "Production workers doing maintenance appeared to perform low-level maintenance, leaving the experts to do substantive work." (Rajan, 1975, p. 27.) Rajan reported retraining and status enhancement of the skills of 75 per cent of supervisors and foremen through retraining by equipment suppliers or external agencies. Coriat (1983) argued that the practice of assigning maintenance to production workers, though possible, is not very common and largely depends on the bargaining power of the trade unions. Nevertheless, putting production workers in charge of maintenance is the most common practice adopted by small firms engaged in batch production using NCMTs in both developed and developing countries (Watanabe, 1985; Chudnovsky, 1985; Senker, 1980).

In the developed world the strategy for maintenance seems to have changed since the diffusion of microelectronics began. At first firms relied on suppliers' maintenance services. There was a shortage of electronic maintenance workers and downtime was increased when firms had to wait for services contracted outside the factory. With the rapid spread of microelectronics equipment the supply of maintenance workers has increased and companies are able to hire their own electronics specialists on a full-time basis. At present there is a trend towards in-house maintenance.

This is crucial in facilitating the adaptation of the quipment and the control unit to the firm's specific needs (Bessant et al., 1985). Moreover, manufacturers of some micro-

electronics equipment, particularly NCMTs, have developed computer-based diagnosis, which might reduce the need for some types of electronic skills within the firm. Some of these new programmes can be operated by data-link over the telephone, a development that may increase the diffusion of certain microelectronic applications in developing countries.

Developing countries usually introduce microelectronic technologies when a reasonable level of local competence is attained in their electromechanical industries. Jacobsson (1983) explains that when NCMTs were first imported into Argentina there was already an adequate pool of mechanics, electronics technicians and also designers for the production of the mechanical part of the machine tool. However, he considers that the electronic components of the NCMTs and the interface were little understood locally.

It has been argued that shortages of electronics technicians and mechanics will limit diffusion of new technologies in developing countries (Kaplinsky, ed., 1982). It is unclear whether shortages are felt within the innovating firms or in the domestic labour market as a whole. This is an ill-researched area. However, studies on technical school graduates trained in microelectronics show a relatively high availability of qualified workers in certain newly industrialised countries (Schwartzman, 1985; Landi, 1982; Gallart, 1984). Nevertheless, distance from suppliers or contract services is undoubtedly a short-term hindrance to successful maintenance, especially for the adaptation of equipment to local needs. However, in the medium term the new developments that simplify maintenance may partially solve the problem of communication at a distance. Telecoe performed by remote control and video screens. There is still the problem of establishing the infrastructure for such advanced communications in developing countries, however. Reliance on complex maintenance functions located in the developed world is not necessarily desirable for developing countries although its feasibility is becoming more likely.

To summarise, the first generations of microelectronic applications required high-level maintenance skills for the electronic components. The skills needed differed from traditional maintenance skills in that the intuitive capacity was reduced and a more one-dimensional approach became necessary. At present a polarisation is taking place. On the one hand there are highly skilled maintenance workers, either mechanics or technicians, rigorously trained in electronics and having a thorough understanding of the technology and its place in the production system. On the other hand, lower-level maintenance work has been deskilled and certain basic functions are sometimes carried out by the machine operators. Less skilled maintenance workers will eventually be displaced from industry in developed countries.

The situation is slightly different in developing countries. New skills and knowledge of basic electronics are required, particularly when microelectronics are first introduced in a country. Training in these skills will be required for a long time, considering the small initial pool of trainees and the distance from specialised services. It is necessary to increase the number of workers skilled in preventive maintenance in order to avoid breakdowns. Operators are likely to assume maintenance tasks only in smaller firms. In the long run there might be increased deskilling of these workers due to the local use of computer programmed repair routines and/or the use of telecommunications for specialised maintenance functions carried out abroad.

II. Microelectronics and white-collar workers

This chapter analyses skill changes brought about by the introduction of microprocessors into office work. It is often stated that microelectronic equipment tends to have deskilling effects on manual work but creates new posts requiring higher-level skills for white-collar workers. A review of the literature will show to what extent this view is justified and for which categories of office workers it is valid.

A. Designers and draftsmen

Engineers and technicians who design microprocessors and systems analysts and programmers who produce the software all work in the offices of industrial firms or in consultancy and service enterprises.

Computer-aided design (CAD) has revolutionised some traditional elements of the work of engineers and technicians. This technology was first applied in the aircraft, aerospace and electronics industries, and its use is at present being extended to a wide variety of other industries, including clothing and textiles. A CAD system consists of microelectronic hardware, predominantly minicomputers, and peripheral components such as TV screens, computer memory and digitising boards. The design stages are analysed and built into the software and then used in different manufacturing applications. The use of CAD systems is essential for the production of such goods as integrated circuits and advanced computers. But CAD can also be used to improve product quality generally and to enhance competitiveness; it is used in this way in the car industry. CAD systems can sometimes be linked into computer-aided manufacturing systems (CAM). The number of CAD systems in the world was estimated at about 8,000 in the early 1980s, approximately half of them linked with CAM systems. The US is considered to be the leader in this field.

Traditionally, design was based on a combination of engineering, mechanical and mathematical principles used to calculate the shape and form of a prototype, its component parts and specifications. This conceptual process demanded constant communication between designer, draftsman and shop-floor operator. Designers were responsible for conceptualising the tool or machine and for calculating its properties. They then instructed the draftsmen to draw the final product and perhaps prepare instructions and specifications to be used on the shop-floor. The whole process took many hours but a CAD system can produce a drawing in a matter of minutes.

Using a CAD system the design engineer obtains the specifications on a cathode ray tube and sketches the product with a special lightpen. The computer transforms the sketch into a final drawing, completing the lines as needed. Drawings can be checked instantly, adapted to different production scales and altered. There are often predetermined menus for the design of tools, i.e. the various ways of producing a tool are built into specific programmes.

The case studies present differing views of the changes in designers' and draftsmen's skills introduced by CAD. Kaplinsky argues that: "It reduces the skill component in drafting because it removes the craft element (requiring extensive practice) associated with individually tailored layouts." (Kaplinsky, 1982, p. 49.) In contrast, he suggests that the

situation is advantageous for the designer as it reduces the unskilled and boring element of the job, so that the work now demands more concentration. Both designers and draftsmen now need to be able to operate a keyboard. The conclusion that CAD has a negative effect on draftsmen and a positive effect on designers is not totally supported by evidence from other case studies. For example, Rothwell and Zegveld argue that the effects of CAD are qualitative. "First, the job content of the technical engineer will be reduced in substance. Secondly, the handicraft-oriented precision-mechanic activities of the draftsman are devalued. Thirdly, the operation of the teletype console and the interpretation of the computer response on the screen become new fields of activity for the technical draftsman." (Rothwell and Zegveld, 1979, p. 120.) For these authors, highly specific skills become more general with the use of CAD systems. The creative work of the designer becomes more abstract because symbolic and mathematical models serve as the medium for planning.

Rader (1981) suggests that a polarisation of skills occurs in the design profession. He differentiates between the following types of necessary competence: general knowledge of electronic data processing, command language, programming and programme logic, and knowledge of the design object, the design method and the organisation. Knowledge of design methods and of command language ranks highest. Rader emphasises that the extent of deskilling in different jobs depends on the precise way in which CAD is applied in the firm. A new division of labour develops: the designer prepares the sketches and the draftsman does the detailed work on the TV screen. Higher-level decisions, formerly made by designers, are now made by programme designers. Engineering specialists, rather than information experts, are usually recruited as programme designers because it is necessary to understand the contents of the programme. This knowledge is a condition for the successful operation of CAD systems. The view that some practical experience of design work is essential for the operation of CAD systems is supported by Cooley, who gives the following illustration: "In the design of an igniter using CAD the decimal point was erroneously shifted one place to the right with the result that the igniter was built ten times too big by unskilled workmen. Some skilled workmen put the igniter on the designer's desk as a sort of joke. But he didn't even realise the igniter was ten times too big." (Cooley, 1980.)

Rosenbrock (1984) has shown that CAD systems can be applied in two ways: to improve the designer's techniques (an interactive process), or to subdivide and codify the design process and reduce it to a sequence of simple choices. There is a consensus in the literature that the latter is the usual pattern. Hence, the conceptualisation tasks of engineers' and draftsmen's jobs are being reduced (Rader, 1981; Hales, 1980; Cooley, 1980).

The distinction between the work performed by draftsmen and that performed by designers is becoming blurred. Junior designers and draftsmen are now performing clerical-type work on the keyboard. A new, elite category of specialist designers is emerging. They have a broad understanding of different CAD programme applications and the training to design the most complex operations. But for most designers and draftsmen the quality of working life seems to deteriorate with the introduction of a CAD system. The literature reports more rigid time schedules, a marked increase in work-intensity, direct machine-pacing of work rhythms and the introduction of night shifts. Many case studies present evidence of high levels of stress among workers.

Kaplinsky (1982b) shows that with conventional technology manufacturing firms had three separate spheres of operation - information control, the production process and distribution. These operations were only integrated through paper information flows. As information becomes digital through the use of microelectronics the different spheres of operation can be systematically integrated, although full integration can only take place when databases are completely unified.

Computer-aided design can be integrated with computer-aided manufacturing (CAD/CAM). An illustration of a CAD/CAM system is given in Shaiken (1982) in the case of machine-setting. NCMT controls can either be linked directly to CAD designs or specifications of the designs can be fed directly from the controls. CAD/CAM makes it possible to integrate the work of the various engineers on a job involving the same CAD database tool. Hence, a systematic reorganisation of the design and manufacturing operation is required when introducing a CAD/CAM system. The reorganisation entails a change from planning before work to planning during work. CAD/CAM facilitates a reduction in the number of shop-floor operators required and the level of their skills, and also reduces the number of engineers needed on a particular job.

B. Programmers

The general increase in employment in data processing seems to support the view that the loss of blue-collar jobs and their partial deskilling through new technology is balanced by employment growth in more highly skilled new professions. Increasing job opportunities may be explained largely by the fact that the computer professionals are new; but this should not be equated with a general upgrading of skills. A closer look at the occupations concerned with producing and using computer software will make the picture clearer.

Software must be produced in a format that is compatible with the hardware in place. Hence the evolution of software largely depends on that of hardware. The programmer's job is complementary to that of the design and electronics engineer; it consists mainly of specifying a detailed sequence of operating instructions in one of the programming languages. Some authors regard most software production as still basically an art form (Kaplinsky, 1982), although a gradual process of job fragmentation has been observed in the work of programmers (Kraft, 1979; Greenbaum, 1976).

Originally the profession derived from electrical engineering and it has evolved through four stages. In the first phase, during the 1950s and early 1960s, programmers had to understand the electrical and mechanical principles of the hardware for which the programmes were written. The job involved the following sequence of operations: defining the approach, designing the programme, instructing the sequence, entering the programme, testing and correcting the programme and maintaining the machine. Early programmers possessed an integral skill and were usually trained at schools of electrical engineering. They were an elite group and their skills were in short supply.

In the second stage, at the end of the 1960s, the separation of conception and execution tasks began. Three different categories of workers emerged. Systems analysts designed a whole system of programmes while programmers became responsible for one particular programme, particularly for writing its operating instructions. Coders carried out a more clerical type of work, setting down the codes that formed the language. Machine-language programming came to be replaced by the use of high-level programming lan-

guages designed by skilled systems analysts. Programmers concentrated on the logic of the problem to be solved. They no longer required a sophisticated understanding of the computer itself. Coding tasks were also simplified by "easier-to-read" languages which have been available since 1965.

In the third stage, during the mid-1970s, the work content of the three occupational categories became really distinct. The development of structured programming was mainly responsible for the separation of tasks. Structured programming defines the method for using standard languages and codes. The choice of instructions is simplified, specified and limited so that there is only one way of generating optimal programmes (Tavares, 1983). Programmes are organised in independent sub-routines or modules, which are handled by a programmer. Management can thus control programming as managers define the problem and analysts design the software to solve it, while programmers and coders simply repeat the same operation over and over again, and lose their understanding of the task as a whole. Each of the programme modules is handled as a coding exercise, which facilitates interchangeability between workers.

The use of ready-made programmes used in simple data-processing tasks such as payrolls and inventories also contributed to this fragmentation. A new type of programmer has been created with the development of ready-made programmes. This is the applications programmer, who adapts standard packages to the specific needs of the firm (Braun and Senker, 1982). Applications programmers need lower-level software skills than the first generation of programmers and they are usually trained as specialist technicians. Only the systems analysts, who are responsible for the design of whole systems, programming languages and large-scale software, are trained at university level. They need a thorough knowledge of applied mathematics, logic and computer science.

In addition to systems analysts and programmers there are also operators who load the computers with data and control its processing. At first these workers tended only one component of a computer system; they were punched-card readers, tape-jockeys, console or main panel operators. However, automatically loaded high-speed tape-drives simplified some of the operations and reduced the number of operators. In addition, centralisation of activities in data-processing firms increased with the use of remote "time-sharing" terminals linking firms and departments. These facilities require fewer operators and programmers. NCMTs and robots can be linked to these terminals through CAD/CAM systems and flexible manufacturing systems. Such systems not only simplify or eliminate the operator's job but also reduce the number of machinists needed for machine surveillance.

The fourth stage in software production is under way in developed countries at present (FAST, 1981). It began with a change in computer hardware design that transformed general purpose computer machinery into special purpose machinery. Most computer hardware is still based on the von Neumann model of the 1930s, which makes a separation between storage and memory. The latest circuits allow the two functions to be integrated and can run data 100 times faster than conventional computers.

This new hardware brings about a change in programming languages. Previously, these languages were sequential, i.e. calculations were made in succession and concurrent operations were impossible. The development of non-procedural languages will reduce computing time by a factor of ten to 20. Non-procedural languages reduce software costs and simplify programming. In

future, the use of natural language, through the development of speech-recognition technologies, and concrete programming, a graphical form of interaction, will cause the programming task and most forms of machine operation to disappear.

As specialisation increases, a need for co-ordination arises between systems analysts, software developers, computer designers, programmers and users. A new type of hardware specialist is emerging - the systems integration contractor. Systems integration contractors put together elements of advanced systems on behalf of users and ensure their compatibility and standardisation. Bessant et al. (1985) maintain that these activities require mastery of communication skills and that such skills will be needed when firms move away from hierarchical structures into network, team and matrix structures which, in the view of these authors, will occur in the near future.

To summarise, in developed countries new trends in hardware and software product professions of software developer and hardware designer. These professions have been subdivided into a hierarchy of different jobs that require diverse skills and training. The top levels of both professions need a knowledge of several different disciplines, preparation in systems thinking and interpersonal skills for team work. Senker emphasises the importance of the latter: "Teams of engineers, mechanical, production and computer specialists are required to get radical developments (robotics assembly, FMS, etc.) from laboratory to factory." (Senker, 1984, p. 139.) However, the lower levels of both professions are either slowly becoming redundant or are experiencing deskilling so that only general skills in information technology are required. Such skills can be acquired in very short training periods. We will now look at the possible implication of these trends for developing countries.

C. Designers and programmers in developing countries

Few studies on the industrial application of microelectronics in developing countries refer explicitly to the effects on the work of designers and programmers. The following analysis is based on the small amount of published material available.

The diffusion of CAD and CAD/CAM systems may be slowed in developing countries by problems of scale. Kaplinsky (1982b) argues that CAD systems are not profitable where there are fewer than ten designers. Assembly-line organisation of programming tasks has similar scale constraints. The volume of production is usually smaller in developing countries and organisational structures are more diverse and less efficient (Katz, 1984). However, some developing countries such as Brazil and India have been able to develop their own CAD software and government incentives are usually available in the newly industrialised countries for this purpose (Jacobsson, 1983). The scant evidence shows that firms introduce CAD systems for reasons other than optimal efficiency. They need to reach certain quality standards for international competition and also respect delivery schedules (Tauile, 1984b; Chudnovsky, 1985).

Geographical distance from software production and servicing may also be a factor slowing down the diffusion of some microlectronics applications in developing countries, since industrial firms often depend on external software skills (Schmitz, 1985). However, packaged software may reduce the need to subcontract highly skilled services from abroad or from foreign suppliers. If this type of software were to be introduced on a massive scale it would deskill the incipient computer professions. This is a possibility in the medium term. More immediate effects may be felt in the civil engineering industries

and professions which have grown in recent years; some even export services to other developing countries (Kaplinsky, 1984). The number of highly trained professionals in civil engineering might be considerably reduced by the introduction of CAD and CAD/CAM systems.

Not all countries lack workers with computer skills. A study quoted by Schwartzman showed that 89.5 per cent of software production in the Brazilian electronics industry in 1984 was generated by local specialists; the same study indicated that 28.7 per cent of employees in electronics had a university degree (Schwartzman, 1985). Chudnovsky (1985) showed that, in the ten applications of CAD/CAM systems operating in Argentina, firms encountered few problems in obtaining the necessary programming skills locally.

In the higher-level professions scarcities will probably arise among electronics engineers, design engineers and systems analysts. However, the main short-term difficulty might be in training middle-level personnel to adapt university training to industrial needs. A Brazilian study on the labour process in software production showed that local programmers and analysts were forced to rely on their own initiative to make this adaptation, the firm being unable to offer guidance (Tavares, 1983). The situation described by Tavares is similar to that in developed countries during the 1970s, although in developing countries the tasks in the profession are not subdivided to the same extent. It is possible that developing countries will suffer from a lack of systems integrator contractors. These professionals are urgently needed to make the diverse microelectronic equipment usually to be found in industry into a compatible working system.

Perhaps one of the main problems faced by developing countries is that the promotion of in-house software skills is slowed down by inadequate reorganisation of firms. Tauile reports difficulties caused by the creation of new departments for software functions in Brazilian firms that had introduced NCMTs. The question at issue was the ranking of programmers within the company hierarchy, indicating that management skills might need to be updated in the light of the organisational change brought about by microelectronics equipment (Tauile, 1984a).

The preceding sections have dealt with the effects of technological change on the skills and job content of workers directly involved with the production of computer hardware and software. In the following two sections we look at the effects on the work of those who use computer systems in the management and administration of industrial enterprises.

D. Managers

The case studies reviewed agree that microelectronics applications in industry require higher management skills. However, the precise nature of the skills is rarely specified and no distinction is made between the different occupational categories: top management, middle management, supervisors and foremen.

The general argument is that higher management skills are required because the decision to introduce microelectronics equipment involves the integration of different spheres of activity and the consequent reorganisation of the firm. For example, the use of CAD/CAM and FMS integrates the stages of design, operation and production. New developments, especially in telematics and computer-integrated manufacturing (CIM) will facilitate the integration of delivery systems, packaging, transport and customer communication, thus resulting in a totally integrated manufacturing operation.

Traditionally, managers at the various hierarchical levels have been responsible for harmonising the stages of production and co-ordinating the work of different departments. At least one-third of managers' time was spent in collecting scattered information in order to make decisions, a very unreliable form of organisation and control. The application of Taylorist strategies of scientific management to manufacturing resulted in the fragmentation of the production process. Shaiken (1982) suggests that this made managements' tasks more demanding and placed obstacles to communication between different types of managers. Several authors now maintain that microelectronics equipment helps reverse fragmentation, integrates different tasks into the same operation and centralises management co-ordination and control (NEDO, 1983; Poppel, 1982; Shaiken, 1982).

The content of management jobs has always involved decision-making, communicating, scheduling and supervising. Microelectronics equipment has contributed to reducing managers' inputs into all these functions and greatly simplified the way they are carried out. Decision-making is simplified by computerised record-keeping and networks of terminals linked throughout the firm or between firms. Scheduling tasks are reduced by the use of electronic agendas, electronic message bureaux and automatic telephone exchanges. Communication is facilitated by word processing, electronic mail and teleconferencing (Verdier, 1983). Supervisory duties are supported by different types of management information systems (MIS).

Management information systems include software packages that can collect, connect and bring up-to-date information on such varied fields as machine monitoring and downtime, absenteeism, stock control, engineering and design. An example of MIS is the Cadillac system which was designed to monitor NCMTs. It collects time-related data, number of parts completed, tool changes, rejects and inspection dimensions. Each terminal throughout the plant has access to this data and the information is stored in the central computer to which each terminal is linked , so that production operations can be analysed as they take place. Some reporting systems have been specially designed for batch production to record up to 1,000 data categories and this type of system can also be applied to assembly-line production .

The use of MIS allows management to extend its control over supervisors, foremen, maintenance workers and machine operators. The nature of foremens' and supervisors' jobs changes substantially with MIS; they monitor the work process through a TV screen in an office, only visiting the shop-floor when something goes wrong. But the result of their intervention is also recorded, and their own job is thus monitored. They now need less knowledge of machine operation than in the past, but they need some skills in information technology to read the information and interpret the data. Rajan (1975) reports that in half the cases studied in industry in the United Kingdom the jobs of supervisors and foremen had been enhanced by technical change. There had been a functional enlargement of their jobs which involved them in different aspects of production, from simple repair to routine maintenance and training. A quarter of the supervisors had been trained by equipment suppliers and external agencies. Their skills might be restricted to a narrower range but their jobs could still be enlarged.

It is not clear if the technical content of most managers' jobs changes dramatically with microelectronics applications, as is sometimes argued (Rothwell and Zegveld, 1979). It is interesting to discover how the knowledge needed for accurate decision-making is acquired. The case studies reviewed record many examples of failure or inefficiency in the introduction and use of new production technologies. These results are usually attributed to the inability of management to make the necessary organisational changes and/or to their unfamiliarity with technical specifications. Below are some examples.

Arnold and Senker (1982) found that managers in mechanical engineering firms in the United Kingdom were slow to learn how to implement CAD. They did not reorganise design adequately or get databases into the system in time. Kaplinsky (1982b) draws similar conclusions on a wide range of inefficient applications of CAD in the United Kingdom and the US. Sciberras et al. (1979) show that insufficient technical expertise led to inadequate planning for the purchase of components of automatic insertion technologies in the consumer durables industries in the United Kingdom. Haywood (1982) has similar findings for the printing industry in the United Kingdom, where managers were shown to lack understanding of the implications of the new technology and thus failed to plan for organisational change and staff training. Partridge (1982) shows that management underestimated costs and space requirements for the full capacity at the most automated FIAT plants in Italy.

The evidence presented certainly indicates a need to upgrade managers' skills. It should be noted, however, that management competence is required for the smooth incorporation of almost any technical change into a production process. The emphasis given to such tasks in the literature suggests that they become even more important when introducing microelectronics as these technologies require a more integrated approach to all aspects of decision-making. The implications of microelectronics equipment for organisational change must be taken into account from the beginning and cannot be tackled in a piecemeal fashion (Kaplinsky, 1982b).

Other authors suggest strategies for tackling some of the problems discussed. Senker (ed., 1980) argues that even when department managers are knowledgeable about the potential benefits of new technologies they lack the data to assess the strategic implications of microelectronics. He suggests that senior management teams should include people who understand microelectronics applications in some detail, and stresses the importance of team-work for the evaluation and introduction of these technologies.

New technologies, especially those involving telecommunications, cause some aspects of management to become more centralised while other aspects become less centralised. The main information-handling activities, general organisation, marketing and control are centralised at the head office of firms while routine management tasks are decentralised to branch offices (Verdier, 1983). The precise technical requirements for managers vary according to the type of office, leading to a distribution of tasks and the need for team-work. In all cases senior managers need to know how best to exploit information technology and they need the ability to work with specialists in economics.

New trends in microelectronics applications are beginning to affect management in developing countries, although this is seldom studied in depth. With CAD systems operating in different countries and telecommunications links between them, the dream of the "global factory" has begun to be a reality. An example of this trend is the production of the world car by Ford, with components made in

Third World countries and designs produced in developed countries. Ford locates parts production for the world factory in Brazil and Mexico because of the availability of skilled manpower and developed infrastructure (Shaiken, 1982; Tauile, 1984b). It is possible that the new technology coupled with a new international division of labour might lead to a loss of decision-making power among top local managers in these multinational sectors.

However, the opposite might be the case in domestically owned or controlled manufacturing, where local managers will need to update their skills in the same way as managers in developed countries. In the case studies there are a number of examples of managers in the newly industrialised countries applying new management techniques to reorganising labour. This is strongly correlated with the introduction of new technologies (Fleury and Vargas, eds., 1983). Routine models of labour control may no longer be effective for organising a labour force that needs to give a quick and collective response to new situations. Management may need creative skills for the design of new, more participatory forms of labour relations.

The development of local telecommunications infrastructure in newly industrialised countries may provide a further incentive for upgrading local management skills. New services require a high degree of management co-ordination to run efficiently and respond to the needs of industry. Whether this will be achieved mainly through the efforts of a few highly skilled top managers or through a general upgrading of management skills remains a matter for further empirical study.

E. Clerical workers: clerks, typists and secretaries

It has been shown that the various applications of microelectronics equipment change the nature of the work in several industrial occupations, so that they begin to resemble clerical jobs. This happens in the case of draftsmen and designers and compositors in the printing industry. However, the work of clerks, typists and secretaries has always been defined as clerical. For more than half a century there has been a gender-based division of labour in administrative office work; male managers occupy positions of authority and female secretaries carry out their orders.

Werneke (1983) listed 18 different types of predominantly female clerical occupations likely to be affected by microelectronics in the US during the 1980s. The main occupations listed for industry were: secretaries, typists, receptionists, billing clerks, telephone operators, stenographers, bookkeepers, filing clerks, office-machine operators and payroll and timekeeping clerks.

Office mechanisation is not new. It dates back to the introduction of the accounting machine in the 1920s (Rothwell and Zegveld, 1979). What is new is the transformation of the work of skilled secretaries by the introduction of the word processor, telecommunications equipment and the integration of different microelectronics technologies into office work. Estimates differ concerning the impact of new office technologies on jobs. Most studies relate to word processors: Pastre (1983) estimated that in France word processors will increase productivity by 50 per cent. Barker and Downing (1980) showed that most firms introducing word processors in the United Kingdom have reduced staff by a half or a third. Siemens in West Germany

reports a loss of 2 million out of 5 million secretarial and typists' posts.

During the 1970s three main types of microelectronic equipment began to have an impact on the character of clerical work. They were word processors, electronic telephone exchanges and electronic data processing. At the same time some organisational changes were made, such as the introduction of the typing pool. The office of the future will see a convergence of technologies that were previously independent, e.g. computing, office systems and telecommunications (Barker and Downing, 1980). Word processors will be linked via computers and telecommunications systems; telex, data and text processing will also be linked.

The most widely diffused innovation so far is the word processor. These machines can operate at 45 characters per second, or 540 words per minute, while an average typist works at 60 words per minute. Only a few detailed case studies are available on how this new technology affects the skills of secretaries and typists. A study conducted by the Bradford Word Processing Study Group (1977) showed how work mobility had been reduced for female clerks in government offices. Traditional office organisation provided the possibility of promotion from junior clerk to typist, to shorthand typist and finally to secretary or team leader. The Bradford study states: "Word processing atrophies these skills and thus destroys the possibility of progression. The scope for promotion is limited, but in addition the knowledge of how the section operated and the nature of the work is lost. The word processing operator has no contact with the source of the particular task, nor any involvement with its destination." (P. 12.)

In word processing, typing is fragmented into keyboarding and printing. Errors are corrected on the machine before printing, thus reducing the need for accuracy. Changes to the text are also made before printing. Text can be standardised from stored documents and the typed work is recorded on diskettes, which reduces the need for filing. Some elements of the traditional typing skill, such as text layout, are performed by word processors (Arnold, Birke and Faulkner, 1981). Thus there seems to be some evidence that word processing deskills typing tasks and increases the intensity of work.

On the other hand, three case studies suggest that deskilling effects may depend on the precise work method chosen (FIET, 1980; Bird, 1980; Broody and Buchanan, 1981). Two of these studies point out that in some cases the tedious part of typing, such as correcting mistakes and tabulating, is eliminated. The third maintains that the possibilities of skill complementarity between typist and machine are usually not explored. However, the opinion of the typists interviewed was that typing work became extremely boring once one was familiar with the machine.

New work arrangements, such as clerical typing pools, have further contributed to deskilling and machine-pacing the work of word processor operators. In this arrangement operators type to standard text and instructions. Training courses for word processor operators vary between two months and four days, very short training being needed for qualified typists to learn to use the new machines.

Word processors increase the skill gap between the work of the typist and that of the secretary (Barker and Downing, 1980). In addition, a new division of labour arises between the correspondence secretary and the private secretary. It is estimated that only 20 per cent of the time of a private secretary is spent in typing, and that the rest of the time

is devoted to numerous other duties that require a wide variety of skills.

The changes in the nature of work are accompanied by more impersonal control methods in offices. Previously, secretarial work was largely dependent on face-to-face supervision and internal motivation. Bureaucratisation in larger offices has led to the application of systematic work procedures and rules, and with word processors it has become possible to control the performance of the operator technologically. Hence, the quality of working life has deteriorated in offices.

According to a survey made by 12 European clerical workers unions (FIET, 1980) the industrial sectors most affected by this new technology are: the engineering industries (including the car industry), iron and steel, electronics, chemicals, aerospace, shipbuilding, clothing, timber, paper, civil air transport, food and drink and construction. Health and safety problems caused by word processors in these industries relate mainly to using VDUs. They include eye-strain, headaches, stress, nausea, skin inflammation and backache. Decreased social contacts also lead to isolation. Verdier (1983) lists some new symptoms found among word processor operators in France: considerable nervous fatigue, increasing difficulty in distinguishing colours and mental fatigue.

We discovered only two studies in the literature on new office technologies in developing countries. They relate to changes in the banking sector in Chile and Uruguay and they provide some evidence on the effects of the technologies on job content and skills (Filgueiras and Argenti, 1985; Vergara, 1985).

Studies on the educational boom of the 1960s in Latin America (Acero, 1979) showed that a large proportion of graduates from secondary and technical schools found employment in clerical jobs in services or industry. Some of their traditional training may be necessary to find work as a typist in word processing or a telephone operator on an automatic switchboard, because of the growing "credentials syndrome" (Oxenham, 1980). Skills and training are demanded by potential employers but not necessarily used. They function as an entry barrier in a period of decreasing job opportunities and downgraded work.

The deskilling of secretarial work is likely to be less pronounced in developing countries, but not only because the diffusion of new technologies is slower. Other factors also play a role. First, it is to be expected that the inertia of traditional practices will be stronger, delaying the reorganisation of office work (Acero, 1983). Second, patriarchal relationships between bosses and their secretaries might mean that conventional forms of work organisation are maintained in small and medium-size firms. At the same time, temporary work and clerical work for specific tasks may be contracted out to modern typing pools equipped with word processors. Third, for successful implementation on a wide scale new office technologies require standardisation of data banks, a systems approach to organisation and adequate telecommunications networks (Rada, 1983). These facilities are still uncommon in most developing countries. Thus it seems appropriate in these countries to maintain a pool of trained and knowledgeable typists, clerks, telephone operators, secretaries and general clerical workers during the first phase of introduction of these new technologies. There is, in fact, some indirect evidence in the banking studies mentioned that enormous difficulties arise when this is not done.

III. Summary and conclusions of the literature review

The case studies reviewed in Chapters II and III indicate that the introduction of microelectronics accelerates and intensifies the changes in the nature of work caused by technological change generally. At the time of writing these changes are less obvious in developing countries than in advanced economies. This can be attributed to three factors: (a) the diffusion of microelectronics is still in its initial stages in developing countries; (b) the patterns of skills and labour use are not necessarily comparable to those in developed countries before the introduction of microelectronics; (c) the new technologies originate in developed countries, so that questions relating to the transfer of technology complicate the issue in the Third World.

The following paragraphs summarise the findings presented in Chapters II and III.

A. Blue-collar production workers

In developed countries skilled manual workers tend to disappear as a distinct occupational category, as in the case of machinists and compositors. The extent to which this occurs depends on the type of technology previously in use. If computer-aided manufacturing is introduced with the first generation of NCMTs it makes more impact on skills and job content than if it is introduced as a second stage of microelectronics applications. At the level of the individual worker microelectronics equipment does not usually produce a straightforward deskilling effect. Decision-making and planning skills are still required but for fewer tasks. Motor skills and manual dexterity are necessary for operating new machines such as NCMTs or robots. Certain other skills are still needed but at a lower level of complexity than for users of conventional technology.

The number of semi-skilled and unskilled workers tends to decrease when microelectronics equipment is introduced, as their work is taken over by the machines. This is true of most assembly operations in the car industry, for example. This pattern was already common with earlier forms of automation based on electromechanical technologies. It is sometimes maintained that microelectronics causes unskilled and semi-skilled jobs to disappear completely. However, the literature review in Chapter II has shown that human intervention is still required to run most of the microelectronic equipment commercially available. Production work is being collectively deskilled by the disappearance of skilled occupations and the heavy reduction in the number of semi-skilled and unskilled workers.

Manual workers who continue to be employed in production need new, though simple, skills. They need to be familiar with information technology, and be prepared to perform clerical-type work on a keyboard; they must also understand the jobs that still require manual intervention and relate them to the overall production operation, particularly in a highly integrated system.

The extent to which the effects described are actually felt depends mainly on the form of work organisation adopted as the range of skills required for individual tasks may be reduced but jobs can be enlarged. However,

we have identified few cases of job enlargement except in small firms where production workers are responsible for programming or low-level maintenance.

B. Maintenance workers

With microelectronics applications maintenance jobs are usually decomposed into two separate functions - electromechanical maintenance and electronic maintenance. The machines themselves do not require higher maintenance skills; it is the job that is split and polarised. Initially, electronic maintenance is usually upgraded and carried out by technicians. Electromechanical maintenance is also split into specialised areas and the majority of low-level functions are assigned to operators. However, the initially upgraded maintenance workers are now experiencing deskilling as a result of new developments that simplify electronics maintenance. On the whole, it seems that only a few selected maintenance workers require multiple skills in electromechanics, electronics, pneumatics and hydraulics.

The trends described for all blue-collar workers tend to become more pronounced when accompanied by a high level of product standardisation, a detailed division of labour and the latest microelectronics equipment.

C. Manual workers in developing countries

Patterns of change among blue-collar production workers in developing countries are basically the same as those in the developed world. Deskilling is more evident in long-established industries such as textiles or food, and in sectors where import substitution has been successful. During the first phases of the diffusion of microelectronics maintenance skills will need to be upgraded to include a basic knowledge of electronics. Distance from suppliers and foreign expertise and the need to adapt the technology to local needs all call for higher maintenance skills. In most newly industrialised countries deskilling is likely to occur among electromechanical maintenance workers. The future of this occupation will largely depend on whether new developments that simplify maintenance tasks come into general use so that sophisticated maintenance skills are concentrated in advanced countries, with telecommunications links to users in the Third World.

If the trend persists towards recruiting younger inexperienced workers to use microelectronic technology, then longer training periods might be needed for the industrial labour force in developing countries than in advanced economies.

D. White-collar workers

Changes in the job content of office workers are very similar to those for manual workers in that jobs tend to be fragmented. The analysis of the case studies in Chapter III challenges the commonly held view that the loss of production workers' skills is balanced by an upgrading of office workers' skills. Skilled white-collar jobs have been restructured through a detailed division of labour facilitated by the new technology. The most obvious example is that of the originally highly skilled profession of software creators. At a lower level a group of semi-skilled workers has appeared. These workers perform a range of different tasks, from telephone operating to coding and low-level management. They require mainly keyboard skills and familiarity with information technology. In addition, an intermediate category of white-collar workers has emerged whose skills are narrower but whose jobs are enlarged compared with workers in convention-

al offices. These are administrative secretaries, some designers and middle-level managers.

Some white-collar occupations have been upgraded as a result of the introduction of microelectronics. The highest grades in most of the professions analysed - specialist engineers, systems analysts and top managers - constitute an elite group whose skills are still to be identified. They are usually multi-skilled, with a good grasp of systems thinking, ability in interpersonal relations and, sometimes, a sophisticated knowledge of electronics. They are responsible for the design of microprocessor software and hardware and for the co-ordination of its applications.

Microelectronics has made a bigger impact on the office environment than upon the shop-floor. Work hazards and social isolation now affect all the white-collar jobs analysed.

E. Office workers in developing countries

In developing countries the deskilling of white-collar jobs is experienced disproportionately by certain categories of clerical workers such as typists, telephone operators and filing clerks. Still, these trends are less visible than in developed countries. The initial introduction of microelectronics equipment generally leads to the creation of new professions and the upgrading of those workers engaged in the adaptation of new technologies to local needs. This applies to computer experts and electronic engineers. The scale of deskilling of white-collar workers in industry depends on the industrialisation strategies applied prior to the introduction of microelectronics. In the longer term job fragmentation will certainly occur in some of the emerging occupations. The development of the software professions has followed the pattern of developed countries and an over-supply of these workers is to be expected in many developing countries.

IV. Training and research needs in developing countries

A. Implications for training

Industrial training policies in developing countries have often been formulated on a general basis for the sector as a whole, ignoring the fact that technological innovations in the different branches of industry cause specific changes in job content and job composition. As a result, firms have often had to train their workforce within the enterprise, through organised courses in larger firms or through supervised on-the-job training in smaller firms. The practice of promoting workers within the sector, from foreman to maintenance worker, for example, has succeeded in developing an adequately skilled labour force.

However, when a new technology is introduced in a firm this type of training is no longer feasible and machine suppliers assume an important role in the initial training of the workforce of the innovating firm. Microelectronics technology exacerbates such problems. User-firms often lack the technical expertise to set up a new training schedule and it can be difficult to obtain assistance, especially if the technology is new to the country as a whole.

The literature review has shown that the workforce generally needs to develop competence in handling information technology when microelectronics equipment is introduced. This applies across occupational categories. The experience of the developed world and some newly industrialised countries has revealed the dangers of channelling resources mainly into training computer experts. Such a policy tends to generate an over-supply of experts, whose skills quickly become obsolete because of the rapid evolution of the new technology from generation to generation.

Trade specific courses to upgrade workers' skills in handling basic electronics might be an appropriate training strategy for many developing countries. Such training could be implemented through vocational training institutions and/or in collaboration with the respective trade unions. Such courses could be directed to retraining workers directly affected by microelectronics and could also provide initial training for newcomers to the industry. It seems advisable to invest in training both manual and clerical workers in basic programming skills. In the future workers will need to adapt to a series of different jobs during their working life and a general competence in handling the new technologies will promote labour mobility and flexibility.

Trade-specific training schemes are equally necessary for intermediate-level workers whose skills are sometimes scarce in developing countries (e.g. maintenance workers, technicians, foremen and draftsmen). The basic training requirements for various trades could be defined by an electronics training board in collaboration with research workers, government officials, entrepreneurs and workers and machine suppliers. Until now intermediate-level training has been given by suppliers, or workers have been trained at headquarters abroad. This trend should be reversed as experience in developed countries has shown that this strategy has a number of disadvantages. The shortcomings include the fact that training goals are narrowly defined in relation to the makers' particular machines, and that it is

often difficult to make such training relevant to the specific needs of the firm. For developing countries the problems of dependence on machine suppliers are exacerbated by distance and possible failure of cummunications.

The literature review has shown that practical experience is still essential for workers in an automated production process, in spite of changes in their job content. Therefore, priority should be given to training or retraining experienced workers rather than new recruits. This strategy would allow firms to concentrate their training resources on short specialised courses for the lower and intermediate grades of both clerical and manual workers.

With regard to the high-level skills needed by managers and systems analysts, training may require the participation of experts from abroad. Government support for this type of university-level training is crucial. The introduction of electronics disciplines into professional training curricula might help to address this need in future. In the meantime short training courses abroad will be needed for selected graduates. Nevertheless, it is recommended that, as far as possible, resources should be devoted to inviting foreign experts to organise courses locally so that theoretical training can alternate with practical experience in the firm.

The changes in job content brought about by microelectronics equipment have, in turn, brought about a redefinition of the composition of trades and occupation categories. The implementation of new training curricula should be based on empirical research into these changes and their impact in developing countries.

The diffusion of microelectronics has caused changes in the sexual division of labour, demanding a special emphasis on training for women workers. There is a danger that the new skills, which require scientific training for higher-level posts, will militate against the increased participation of women in the industrial labour force. Special boards, similar to the Equal Opportunities Commission in the United Kingdom, should be set up in developing countries to encourage women to retrain and to promote non-discrimination in occupations socially defined as "men's jobs".

The whole strategy suggested here focuses on training for stock rather than on training for present needs. The recommendations are directed towards upgrading local capabilities in the short term, regardless of whether posts will be deskilled in the long term. The strategy is feasible as the modular character of digital technology itself favours the organisation of training modules (Hobday, 1984).

In the medium term formal education curricula should be upgraded, both in schools and in higher education. It is necessary to prepare young people to adapt to constantly changing conditions. However, there is an immediate need to familiarise adult workers with the new technology, especially the educators and trainers themselves. In developing countries the principle of lifelong education needs to be taken more seriously than ever before and steps should be taken to implement economically viable training policies directed to this end.

Finally, a special effort should be made to standardise information on the successful diffusion of new technology in a database accessible to all developing countries. Specially trained educators could perhaps collaborate in preparing such a database and information network.

However, before these steps can be adequately planned and implemented, more empirical research is needed on the labour effects of automation in developing countries. The next section very briefly discusses what needs to be done in this respect.

B. Research needs

This paper has referred several times to the scarcity of detailed studies on the effects of microelectronics on skills and job content in developing countries. This is partly a reflection of the fact that industry in these countries has only recently begun to use microelectronics-based technologies, but it should be pointed out that there is also a lack of studies on the effects of earlier technologies.

A systematic approach to research into the impact of microelectronics requires the preparation of case studies at both sectoral and enterprise level. The studies should focus on the nature of work rather than the level of employment, as it is probably too early yet to reach any firm conclusions on the latter. The direct effects of new technologies are best understood at the sectoral or enterprise level, while indirect effects need to be researched through inter-sectoral studies. It is necessary to strike a balance between the two types of study.

In the developed world there is a disproportionate amount of information available on the effects of new technologies in the engineering industries, on industrial robots and automated transfer lines in the car industry, on word processors in offices and on CAD applied to drafting and printing. The studies usually pay more attention to labour use than to skills and changes in the nature of work. In contrast, there are relatively few studies on FMS, CAD/CAM systems, telecommunications applied to office work or the production of software for the electronic hardware industries.

A similar though more acute imbalance exists in studies on developing countries. Most attention has been paid to the effects of NCMTs. More studies are needed on different microelectronics applications, particularly on the long-established and traditional industries.

Methodology should be considered in planning research, as many studies in both developed and developing countries have a number of flaws. First, skill changes are not usually studied in detail and little attempt is made to identify the new skills required for particular jobs. Second, few studies include an analysis of work changes. Third, workers are very seldom taken as the subject of the study; sometimes very broad occupational and social categories are used, which do not permit a useful characterisation of the workforce. Fourth, workers' interview responses are rarely treated in a way that is statistically valid.

New case study research should endeavour to overcome such shortcomings and produce information which will be useful to policy-makers and planners of training. A more realistic and detailed picture of the workers remaining in an industry after automation is a prerequisite to appropriate decision-making. New research is also needed on the scientific and technical training opportunities opening up for some categories of workers in electronics and software production. Such data will make it possible to compare the demand for such workers with the skill mix presently available.

Finally, inter-country studies are needed, focusing on the impact of the same technology on the same branch but in different developing countries. National differences in

labour use and diffusion levels can then be distinguished for common structural trends.

There is an urgent need for research in this field.

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